A Review on Manganese Bio Mining

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ABSTRACT: Bio mining is the use of microbial methods to process and extract metals from their ores and concentrates. Currently, the mining industry uses this method to extract copper, uranium, and gold from low-grade ores, but not on an industrial scale for low-grade manganese ore. Microbial genomics is the study of the genomes of microorganisms. Novel insights into the metabolism of bioleaching bacteria are provided by metabolites and regulatory mechanisms and how they work together during bioleaching activities This can help people understand the bio mining microbial community's universal regulatory responses to adapt to their changing environment. This creates a favorable environment for metal recovery. There's a chance you'll be able to figure out how to duplicate the whole thing. During the industrial manganese bio mining process, the present state of manganese is examined in this article. Identifies variables that influence the selection of bio mining research activities throughout the globe.as a processing technique, discusses the difficulties in commercializing these advances, and concludes includes a discussion on the future of Mn bio mining.

KEYWORDS: Bio mining, Bioleaching, Manganese Bio mining, Microorganisms.

INTRODUCTION

In the current situation, bio mining technological advancements are focused on increasing the effectiveness of bioleaching microorganisms in order to achieve efficient precious metal recovery. This has to do with manganese-oxidizing microorganisms' solubilizing activity and the speciation of intermediate compounds produced during bioleaching processes. Due to an increase in steel production over the years and a rising scarcity of natural resources, the demand for manganese ore has risen significantly[1]. Aside from effective manganese production throughout the globe, there is still a high-grade manganese ore scarcity in international markets for carbon steels. As a result, both manganese ores and alloys have seen price increases. Manganese will be in high demand for steel production in order to meet the anticipated demand for Ferro alloys. The constantly increasing global demand for manganese has made developing methods for economically recovering manganese from low-grade manganese ores more essential [2]. Due to high energy and capital requirements, recovering metals from low-grade ores using existing pyro metallurgical and hydrometallurgical methods is prohibitively costly. Massive quantities of solid mine wastes and mine effluents have been generated as a consequence of significant mining, metallurgical, and other human operations. The poor management of metallic effluents has led in heavy metal mobilization in the environment, soil contamination, groundwater pollution, and a slew of other severe environmental issues [3]. Due to the high metal concentration in it, which may range from approximately 4% (w/w) in general to as high as 15% in certain instances, unprocessed metal liberation leads in a massive loss of valuable elements like manganese. Manganese use in the globe exceeds 1,500,000 tons per year, and it is expected to increase. According to the International Manganese Institute, the European Union's (EU) manganese dioxide mineral resources are restricted [4]. Due to the fast rise in metal demand, global stocks of high-grade manganese ores are dwindling at an alarming pace. Manganese is found in abundance in Russia, Australia, Gabon, Brazil, South Africa, and India. High-grade manganese ore deposits in India are very restricted, with mining taking place in the states of Madhya Pradesh, Orissa, Maharashtra, and Karnataka. According to the National Steel Policy, planned steel output is anticipated to reach 60–70 million tons in 2009–2010 and 110 million tons by 2020, according to Manganese Ore India Limited (MOIL). Manganese ore is usually categorized into three classes depending on its manganese concentration [5]. Medium and low grade ores include 35–44 percent and 25–35 percent Mn, respectively, whereas high grade ores contain more than 44–48 percent Mn. Since no grade steel can be made without the addition of a tiny quantity of manganese, about 95 percent of total Mn ore output is used in steel manufacturing to create Ferro-manganese-alloys. It is utilized as a unique deoxidizing and desulfurizing agent in steel to improve its quality. Pyro metallurgical techniques are often used to convert high-grade manganese ores into acceptable metallic alloy forms. Due to the rapidly rising demand for manganese metal from the aluminum/steel industry and battery industries, conventional pyro metallurgical reductive roasting followed by hydro metallurgical processing of low grade manganese ores is done for the manufacture of chemical manganese dioxide (CMD) or electrolytic manganese dioxide (EMD)[6]. Manganese compounds have non-metallurgical applications. EMD use in alkaline batteries surpassed 230,000 tons per year in 2002, with an annual growth rate of more than 9.6% between 1996 and 2002. As worldwide demand for batteries grows in sectors like mobile communications, future growth in the EMD industry is anticipated to outpace current growth rates. Bioleaching with different microorganisms to recover manganese from manganic ferrous ores is a better green alternative to pyro metallurgical and hydrometallurgical techniques for the release of metals from solid materials such as metal-polluted soil, low-grade ore, and spent batteries with higher efficiency and lower cost. Bio mining commercial allows a wide variety of microorganisms to flourish. Several significant breakthroughs in the area of geo microbiology have been made thanks to developments in genomics, proteomics, molecular biological methods, genetics, and bioinformatics[7].

Molecular methods, for example, have shown that at least one Gram-negative bacteria may import electrons supplied by an electro donor, ferrous iron, in contact with the outside surface of the organism's outer membrane. Microbes have a critical role in the transformation, oxidation, and reduction of minerals, according to these findings. We believe that these new biotechnological methods will be progressively used to a variety of geo microbiological issues. This review focuses on the current application of universal prospective and integrative methods to investigate manganese bio mining and microorganism communities. Manganese is the earth's second most plentiful metal and the 12th most abundant element[8]. The oxide ore layers are interbedded with iron-rich strata in most ore deposits, which are sedimentary in nature. The Paleoproterozoic hazel formation in South Africa contains over 13.5 billion metric tons of manganese ore 4 billion tons of Mn, making the Kalahari manganese field the world's largest land-based economic reserve of this element. Previous theories have suggested a global glaciation followed by a cyanobacterial bloom as a simple explanation for manganese-rich formations. The study outlines a once-in-a-lifetime occurrence that may have far-reaching consequences for life's development. Only two major Mn deposits linked with banded iron formations have been found in the geological record, and both occur after presumed Paleo Proterozoic snowball Earth occurrences. Paleoproterozoic and Neoproterozoic are two different periods of time. The deposition of the Kalahari manganese field constitutes a unique oxidation and Mn extraction event in the global seas, according to geochemical studies of Mn concentrations in shallow-water carbonates[9].

Manganese is found as a significant or minor component in over 100 naturally occurring minerals in the form of oxides, carbonates, and silicates. Pyrolusite (MnO_2) is the most prevalent Mn mineral, and it is found all over the globe. Manganese oxide ores are produced by terrestrial weathering processes and may be found in a wide range of locations throughout the globe, with varying morphology, chemistry, and physical properties. Moderately alkaline and reducing circumstances, normal electrical conductivity, sandy texture, and medium-to-high cation exchange capacities all favored the presence of Mn^{2+} in soil and sediments. The majority of economically viable manganese ores come from hydrothermal vents associated with intermediate volcanic rocks. In the mineral map of India in general, and manganese ores in particular, the state of Orissa has a prominent place. Crypto melena, romanechite, and pyrolusite are the main manganese minerals found in this region, with small quantities of Jacobite, hausmannite, braunite, lithiophorite, birnessite, pyrophanite, graphite, hematite, and magnetite.

The gangue minerals associated with these ores include the various opaque minerals as well as quartz, zircon, biotite, and muscovite. In the Bonai- Keonjhar belt in north Orissa, India, there are many mesa scale Mn–Fe oxide and Monoxide deposits. Different commercial and government organizations have been mining these resources in Orissa and Jharkhand since the twentieth century. In contrast to other manganese resources in India, the manganese ores are generally low to medium grade with little phosphorus concentration. From this belt, three kinds of low-grade Mn-ore have been reported: (a) siliceous, (b) ferruginous, and (c) aluminous. Secondary manganese sources include discarded batteries and wasted electrodes, steel scraps, sludge, and slag, among others. Manganese mineral is often leached and dumped with other ores, therefore manganese mineral including effluents may be a major manganese supply. For example, the nickel/manganese concentration ratio in the leach solution of Mineral Resources Ltd.'s Murrin Operation is in the order of 2:1. It now produces 36,000 tons of nickel per year. As a result, the amount of manganese in the waste stream is about 18,000 tons per year. Manganese is found in a variety of oxidation levels ranging from 0 to +7, although only the +2, +3, and +4 oxidation states have biological significance in nature. Only manganese in the +2 oxidation state may exist as a free ion in aqueous solution out of the three naturally occurring oxidation states. Only when manganese is complexed can it be found in aqueous solution in the +3 oxidation state. The disproportionate oxidation states of the free +3 ion are +2 and +4. Manganese +4 oxides (mostly MnO_2) are insoluble in water. Manganese is recovered from manganese oxide ore under reducing circumstances because MnO_2 is stable under acid or alkaline oxidizing conditions. Fig. 1, Illustrates the process of bio mining of natural resources like minerals.

Fig. 1: Illustrates the process of bio mining of natural resources like minerals [10].

Different feasible hydrometallurgical techniques for recovering manganese from low-grade manganese ores have recently been discovered. The ores are reduced by roasting followed by acid leaching or by reductive acid leaching directly using various acidic reducing agents and acids, such as hydrochloric acid and pyrite, iron(II) sulfate, aqueous sulfur dioxide, hydrogen peroxide in acidic medium, mixed methanol sulfuric acid solution, an aqueous alcoholic–HCl acid mixture, sulfuric acid and oxalic acid glucose. The use of corncob as a reductant and biomass straw as a reductant to extract manganese from low-grade manganese dioxide ores in sulfuric acid solution has been described in the literature. They hypothesized that the biomass straw was degraded to generate CO gas through a biomass gasification process in which manganese oxides in the original ore, such as MnO_2, Mn_2O_3, and Mn_3O_4, are reduced to MnO. When the temperature was regulated above 32^0C, the thermal breakdown of biomass resulted in the reduction of manganese oxides in ore in a carbon monoxide environment. The existence of various microorganisms with enzymes capable of oxidizing and reducing manganese has been reported, many of which are taxonomically unrelated group" is a phylogenetically diverse group of microorganisms classified by their ability to catalyze the oxidation of divalent, soluble Mn(II) to insoluble manganese oxides. The oxidation of Mn^{2+} is catalyzed by a broad range of microorganisms in aerobic conditions.

DISCUSSION

Deep sea manganese nodules, toxic/anoxic interfaces in fjords, manganese-rich surface films of shallow lakes and freshwater lake sediments, and ferromanganese deposits are only a few examples of environments where numerous manganese oxidizers have been discovered by morphology alone and/or isolation. Furthermore, Mn^{2+}-oxidizing bacteria have been found in environmental samples polluted with xenobiotic that are difficult to degrade, such as polycyclic aromatic hydrocarbons or methyl tertbutyl ether. Information about manganese oxidizing bacteria and fungi that have been isolated and identified from various environments. Manganese oxidation has been observed in many mycelium-forming fungus; in most cases, this oxidation is non-enzymatic and occurs as a result of contact with a fungi metabolic product (e.g., hydroxyl acid) or a fungal cell component. However, in certain fungi, such as the white rot fungus Phanerochaete chrysosporium, oxidation may be caused by an external Mn(II)-dependent peroxidase that consumes H_2O_2 and oxidizes Mn(II) to Mn(III). Some researchers believe Mn^{2+}-oxidizing organisms collect Mn oxides as electron acceptors in order to survive in anaerobic or microaerophilic environments. Microorganisms may speed up Mn^{2+} oxidation by up to five orders of magnitude when compared to abiotic Mn^{2+} oxidation. Microorganisms that may oxidize manganese enzymatically or non-enzymatically are included. In order to achieve Manganese reduction has been recorded by a variety of taxonomically diverse bacteria, both enzymatically and non-enzymatically. Bacteria that reduce manganese enzymatically do so as part of a respiration process in which oxidized manganese acts as a terminal electron acceptor and is reduced to Mn (II). Aerobes and facultative anaerobes are among the manganese-reducing bacteria, and manganese may be reduced to meet a nutritional requirement for soluble Mn (II). Some of them promote manganese oxidation enzymatically, whereas others do it non -enzymatically, and it is yet unclear whether they do so enzymatically or non-enzymatically. Mn oxides generated aerobically, under low oxygen or anaerobic conditions have been demonstrated to be reduced by a variety of Mn^{2+} oxidizing species. The physiological relevance of the reduction mechanisms in these organisms is unknown since anaerobic growth of these species using Mn oxide as an electron acceptor has not been shown. Mn oxides consume complex humid molecules, producing low molecular mass organic compounds (e.g., pyruvate) that may serve as substrates for bacterial growth, which is an intriguing hypothesis for the role of microbial Mn^{2+} oxidation. This suggests that Mn^{2+} oxidizing bacteria may thrive in low-nutrient settings by generating a powerful oxidizing agent capable of degrading physiologically intractable carbon pools. Mn^{2+} oxidizing bacteria may be likened to wood-degrading fungus, which produce peroxidases and laccases that can lyse lignin. The production of Mn(III) complexes, which may then oxidize phenolic compounds, is catalyzed by fungal manganese peroxidases. Some bacteria, such as Lactobacilli, collect Mn to mill molar levels in the cytoplasm and strictly exclude iron, as a non -enzymatic method of protecting against peroxide-mediated oxidative damage, and others to provide radiation protection. Certain blood-borne viruses, such as, utilize an iron-free, Mn-dependent lifestyle to avoid iron sequestration by their hosts; Weinberg, in nature, other enzymes such as cellobiose dehydrogenase (CDH), an extracellular enzyme, play a part in Mn redox cycling. They showed that this enzyme can reduce insoluble MnO_2 and generate Mn(II), which is the MN substrate. Many microbial species have recently been identified that can combine anaerobic organic carbon respiration with metal reduction, including oxidized Mn. Despite many studies pointing to particular functions for enzymatic Mn^{2+} oxidation by bacteria, there is still a lack of unambiguous evidence for the different functional hypotheses. Only by elucidating the processes of Mn^{2+} oxidation in specific bacterial species and identifying the cellular components involved will the function(s) of Mn^{2+} oxidation be revealed. When trying to bioleach Mn from low-grade ores for extraction of Mn from the solid phase to the liquid aqueous phase, reduction of Mn(IV) to Mn(II) is crucial. ‘‘Bio mining" is a broad word that encompasses bioleaching, bio oxidation, and bio mineralization methods. Recent advances in molecular biology, chemical analysis, bio hydrometallurgy, surface science, and nanotechnology have led to a better understanding of such bioprocesses. A well-established biotechnology is the use of microbes capable of oxidizing iron and sulfur in industrial procedures to extract metals from low-grade mineral ores including manganese, copper, gold, and uranium. In addition to chemical leaching methods, biological therapy, which typically employs heterotrophic microorganisms, has received a lot of attention. Living organisms, particularly microorganisms, may accelerate the conversion of Mn between oxidation states. The bioleaching process may be described as the solubilization of metals from solid substrates, either directly or indirectly, via the metabolism of leaching microorganisms. Reducing and oxidizing microbial species may offer fast Mn cycling across the toxic anoxic border in stratified settings. Manganese bioleaching has both direct and indirect mechanisms. In a direct leaching process, bacteria may use MnO_2 instead of oxygen as a final acceptor of electrons in the respiratory chain of their metabolism. The reductive process is linked to the production of reductive chemicals as a consequence of microbial metabolism in the indirect mechanism. The bioleaching process was shown to be mostly indirect, involving the formation of organic acids in the leaching media, namely oxalic acid and citric acid, which decreased manganese oxides. The biological process takes place in the presence of organic carbon and energy sources in all situations. Several investigations have shown the reduction of Mn(IV) by microorganisms. Many anaerobic bacteria may decrease Mn oxides by producing acids or reducing compounds like sulfides, or by utilizing the oxidized metal as an electron acceptor during respiration. The reduction of Mn oxides to $MnCO_3$ by microorganisms in sewage was the first confirmed report of microbial Mn reduction. Mn(III) or Mn(IV) oxides may be reduced by a wide variety of microorganisms, including bacteria, algae, yeast, and fungus. Metabolically expelled end products such as for mate, malate, oxalate, citrate, and other organic acids are thought to be involved indirectly in the microbial Mn reduction process under aerobic circumstances. Cellobiose dehydrogenase is one of the enzymes used. Despite the difficulty, efforts have lately been made to combine heterogeneous ‘omics' information in different microbial systems, with the findings demonstrating that the multi-omics' method is a valuable tool for understanding the functional principles and dynamics of whole cellular systems. The exciting new results of the OMICS method are giving new insights that will enable predictions on how to maintain the microbial consortia healthy and competent throughout the bioleaching process. Biologists have gained a better understanding of microbial metabolism thanks to computational and comparative genomic analyses of DNA sequences, which have provided information about gene function, genome structures, biological pathways, metabolic and regulatory networks, and evolution of microbial genomes.

CONCLUSION

The present state of knowledge on manganese bio mining is reviewed, as well as the significance of this process in terms of bioleaching microorganisms. Understanding the microorganisms engaged in manganese bioleaching at a molecular level would aid in optimizing the reaction kinetics that are so important in bioprocessing low-grade ores. The ability to investigate the physiological manifestations of bio mining animals has been made possible by remarkable developments in molecular technology. Researchers are getting an unparalleled picture of the molecular components of microbial cells and their interactions thanks to omics methods.

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